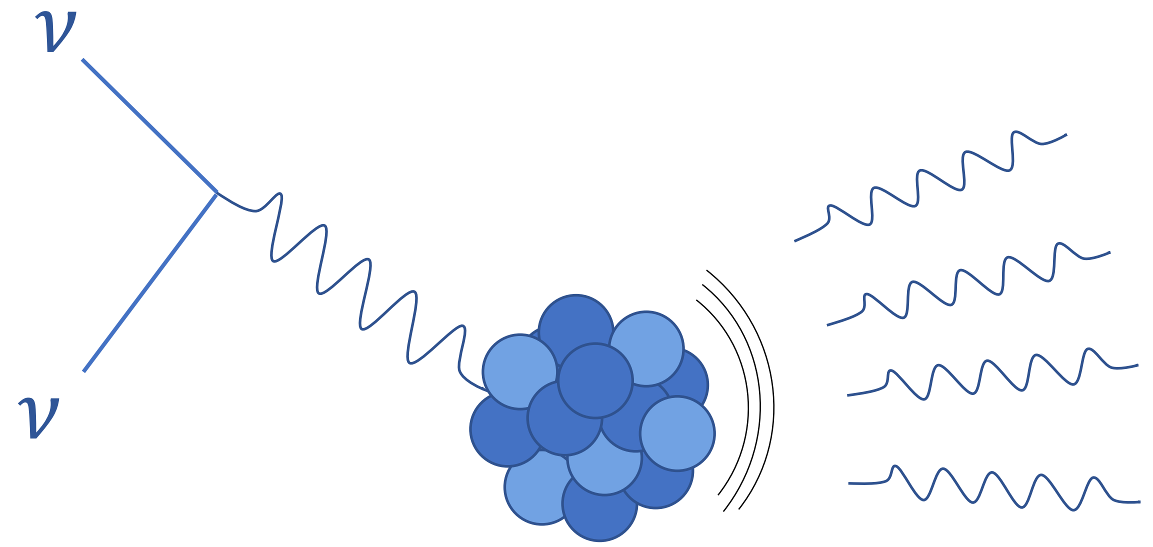
Beyond the Standard Model and Nuclear Properties in CEvNS



Gonzalo Sánchez García

IFIC (CSIC/UV)

EPIC 2024, Sardinia

gsanchez@ific.uv.es

IFIC INSTITUT DE FÍSICA CORPUSCULAR · CSIC · VNIVERSITAT DE VALÈNCIA · GENERALITAT VALENCIANA Conselleria d'Educació, Universitats i Ocupació · MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES · Financiado por la Unión Europea NextGenerationEU · Plan de Recuperación, Transformación y Resiliencia · AGENCIA ESTATAL DE INVESTIGACIÓN

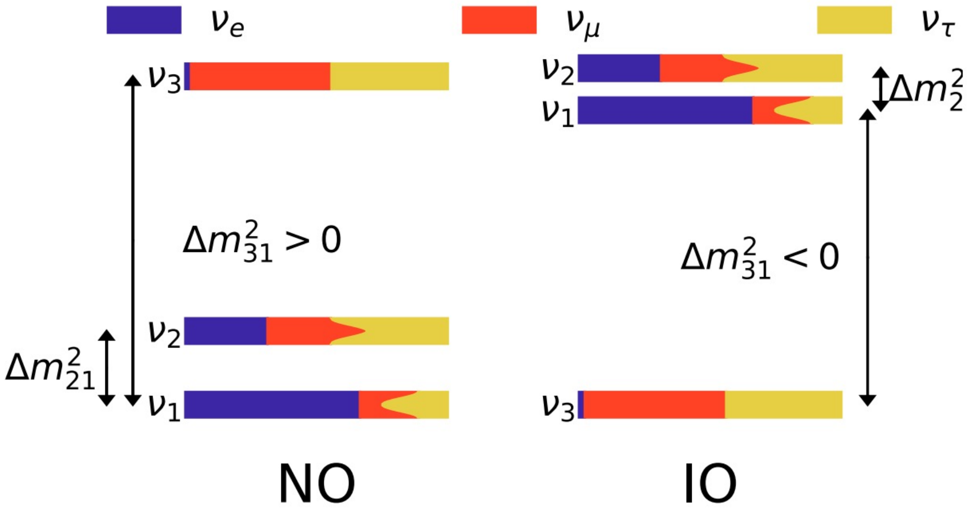
Outline

- Introduction
- Coherent Elastic Neutrino-Nucleus Scattering
- The COHERENT experiment
- The European Spallation Source
- Non-Standard Interactions
- Electromagnetic Properties of neutrinos

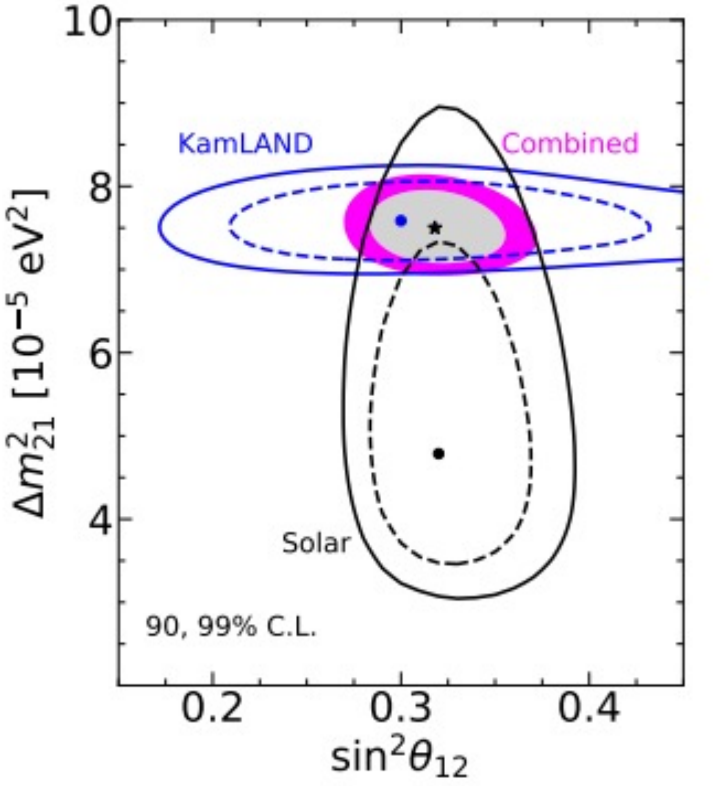
Current Picture of Neutrino Physics

Neutrinos are massive.

What is the lightest neutrino?



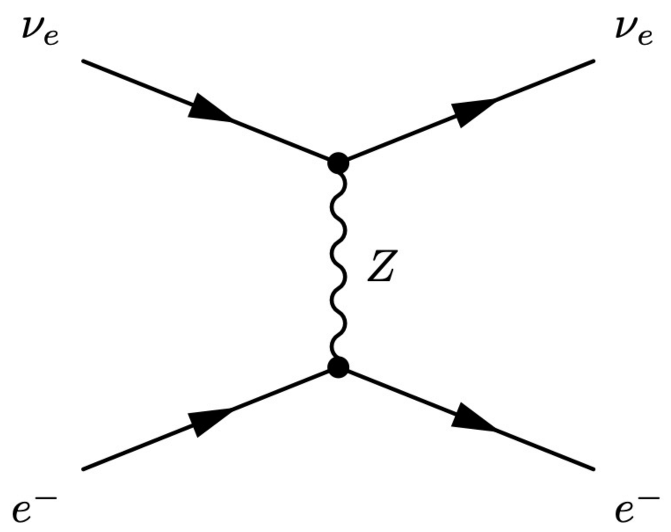
What is the absolute scale of neutrino mass?



P. Salas, D. Forero, P. Martinez, O. Mena, C. Ternes, M. Tortola, and J. Valle JHEP02(2021)071

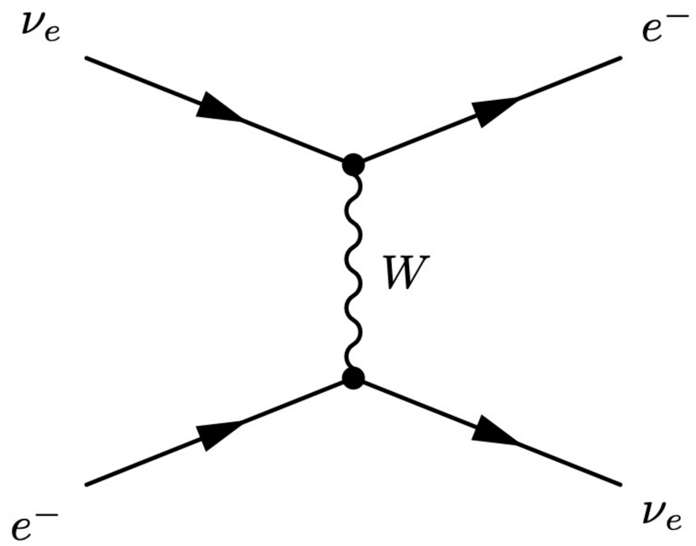
Neutrino Interactions

Neutral Current Interactions



$$\mathfrak{L} \propto (\bar{\nu}_L \gamma^\mu \nu_L)\left(g_L^l \bar{e}_L \gamma^\mu e_L + g_R^l \bar{e}_R \gamma^\mu e_R\right)$$

Charged Current Interactions



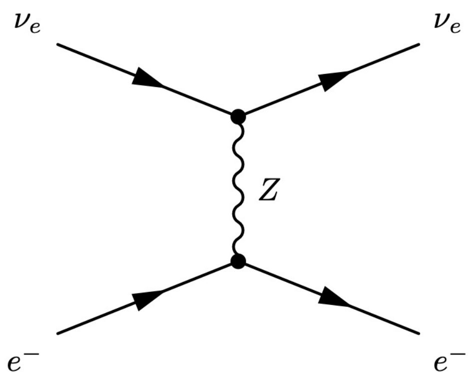
$$\mathfrak{L} \propto (\bar{\nu}_L \gamma^\mu \nu_L)(\bar{e}_L \gamma^\mu e_L + \bar{e}_R \gamma^\mu e_R)$$

Neutrino Interactions

Small cross section

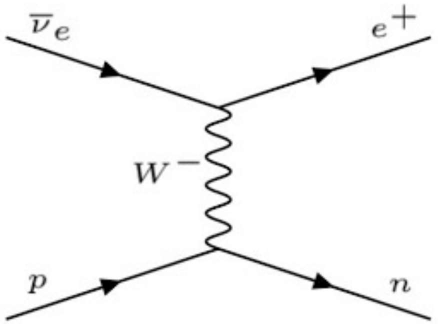
Large detectors!

Neutrino-electron elastic scattering

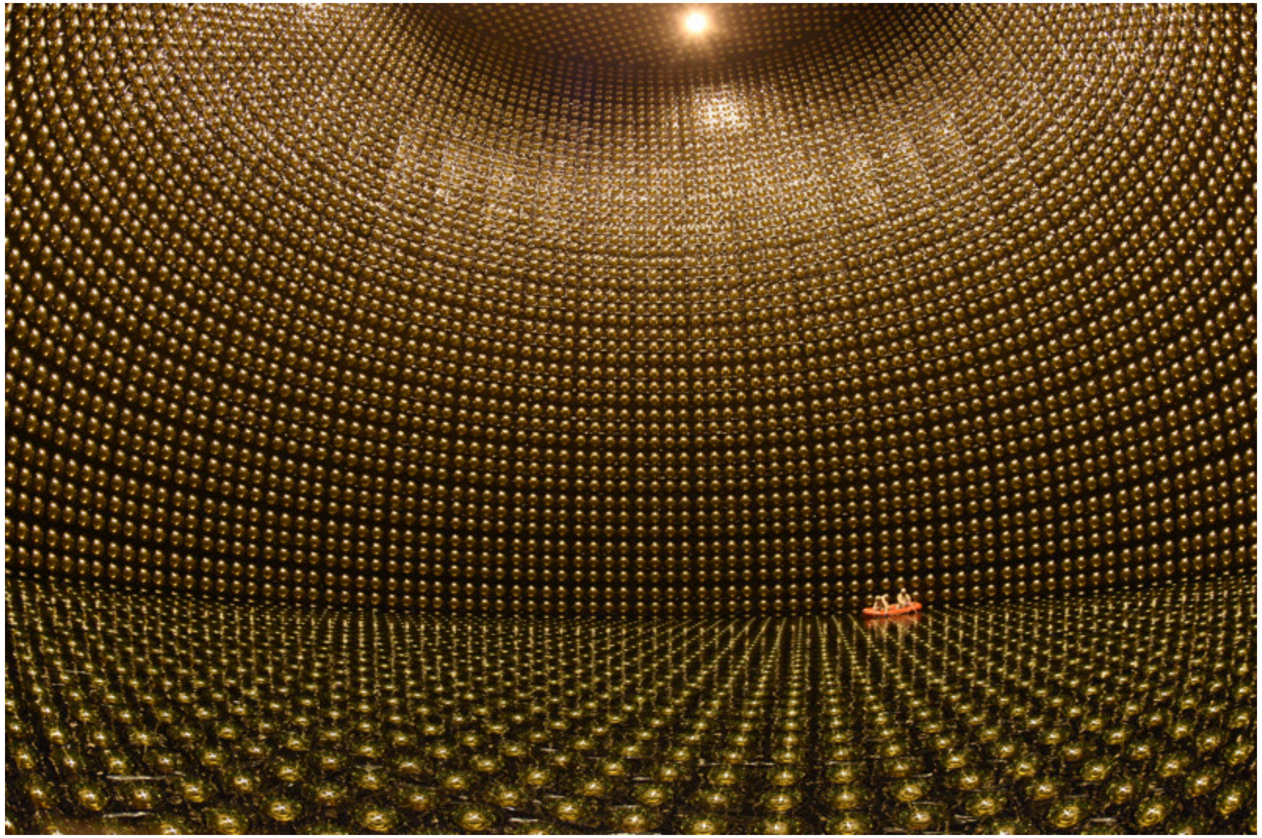


$$\sigma \approx 10^{-44}\ \mathrm{cm}^2$$

Inverse beta decay

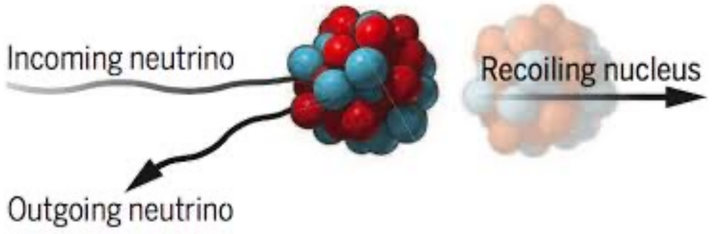


$$\sigma \approx 10^{-42}\ \mathrm{cm}^2$$



https://sk.icrr.u-tokyo.ac.jp

Coherent **E**lastic **N**eutrino **N**ucleus **S**cattering



D. Z. Freedman, Phys. Rev. D 9 (1974)
COHERENT Collaboration, Science 357 (2017) 6356

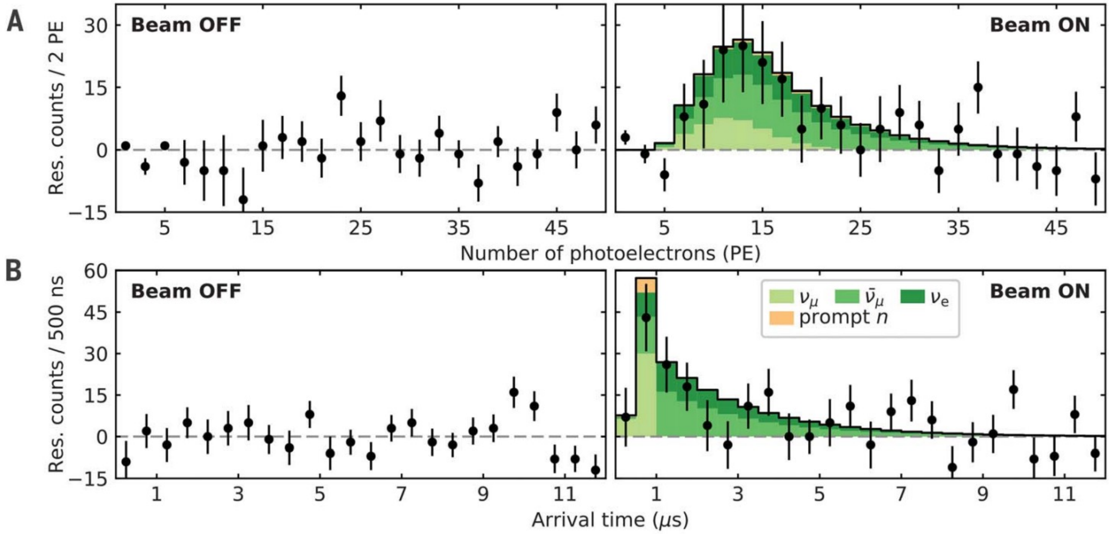
PHYSICAL REVIEW D VOLUME 9, NUMBER 5 1 MARCH 1974

Coherent effects of a weak neutral current

Daniel Z. Freedman†
National Accelerator Laboratory, Batavia, Illinois 60510
and Institute for Theoretical Physics, State University of New York, Stony Brook, New York 11790
(Received 15 October 1973; revised manuscript received 19 November 1973)

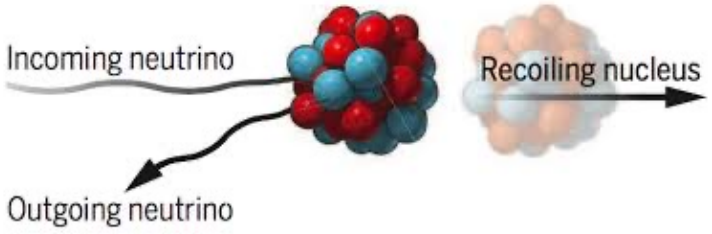
If there is a weak neutral current, then the elastic scattering process $\nu + A \to \nu + A$ should have a sharp coherent forward peak just as $e + A \to e + A$ does. Experiments to observe this peak can give important information on the isospin structure of the neutral current. The experiments are very difficult, although the estimated cross sections (about 10^{-38} cm^2 on carbon) are favorable. The coherent cross sections (in contrast to incoherent) are almost energy-independent. Therefore, energies as low as 100 MeV may be suitable. Quasi-coherent nuclear excitation processes $\nu + A \to \nu + A^*$ provide possible tests of the conservation of the weak neutral current. Because of strong coherent effects at very low energies, the nuclear elastic scattering process may be important in inhibiting cooling by neutrino emission in stellar collapse and neutron stars.

50 years since first proposal by Freedman!



7 years since first detection by COHERENT!

Coherent
Elastic
νeutrino
Nucleus
Scattering



D. Z. Freedman, Phys. Rev. D 9 (1974)
COHERENT Collaboration, Science 357 (2017) 6356

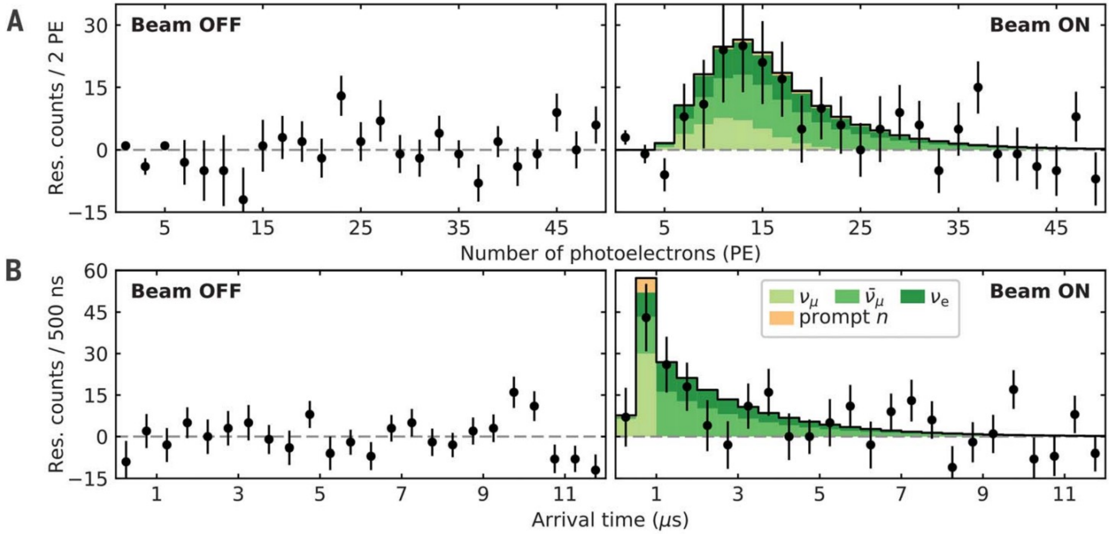
PHYSICAL REVIEW D VOLUME 9, NUMBER 5 1 MARCH 1974

Coherent effects of a weak neutral current

Daniel Z. Freedman†
National Accelerator Laboratory, Batavia, Illinois 60510
and Institute for Theoretical Physics, State University of New York, Stony Brook, New York 11790
(Received 15 October 1973; revised manuscript received 19 November 1973)

If there is a weak neutral current, then the elastic scattering process $\nu + A \to \nu + A$ should have a sharp coherent forward peak just as $e + A \to e + A$ does. Experiments to observe this peak can give important information on the isospin structure of the neutral current. The experiments are very difficult, although the estimated cross sections (about 10^{-38} cm^2 on carbon) are favorable. The coherent cross sections (in contrast to incoherent) are almost energy-independent. Therefore, energies as low as 100 MeV may be suitable. Quasi-coherent nuclear excitation processes $\nu + A \to \nu + A^*$ provide possible tests of the conservation of the weak neutral current. Because of strong coherent effects at very low energies, the nuclear elastic scattering process may be important in inhibiting cooling by neutrino emission in stellar collapse and neutron stars.

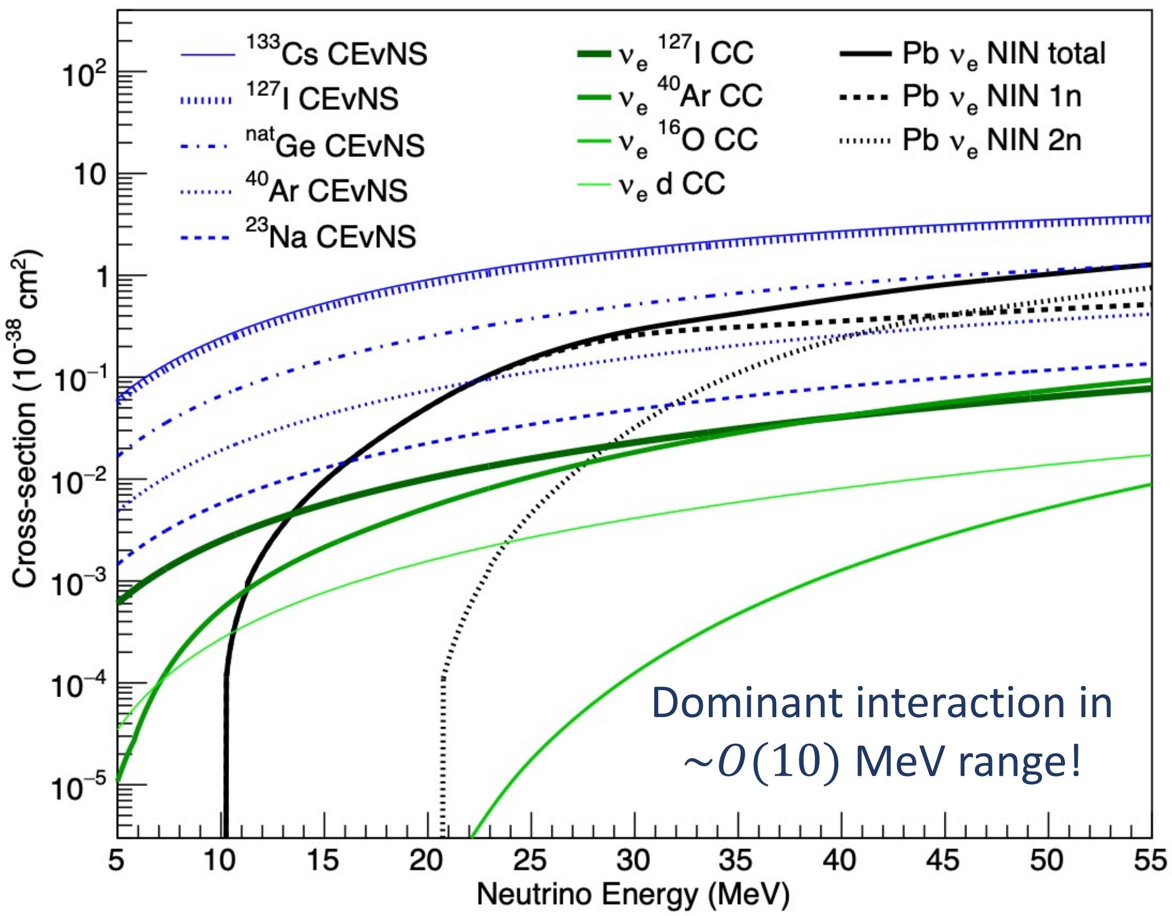
50 years since first proposal by Freedman!



7 years since first detection by COHERENT!

CEνNS in the Standard Model

A neutral current process



Diana Parno's Talk at Magnificent CEvNS 2024

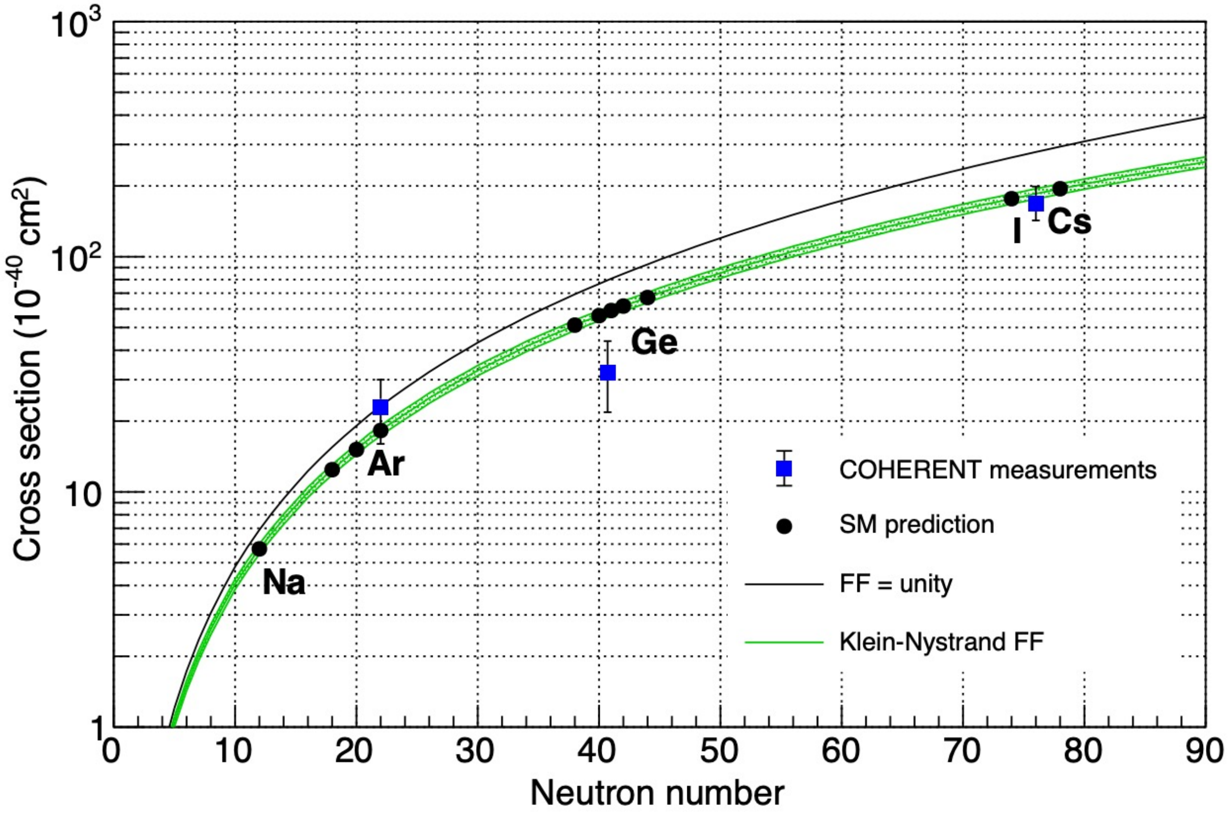
The good news

- Large cross section.
- Small detectors needed.

The not so good news

- Very low energy thresholds.

Origin of the cross-section enhancement



Matthew Green's Talk Neutrino 2024

Cross-section

$$\left.\frac{d\sigma_{\nu\mathcal{N}}}{dE_{\rm nr}}\right|^{\rm SM}_{\rm CE\nu NS} = \frac{G_F^2 m_N}{\pi} F_W^2(|\vec{q}|^2)\left(Q_V^{\rm SM}\right)^2\left(1 - \frac{m_N E_{\rm nr}}{2E_\nu^2}\right)$$

$$\left(Q_V^{SM}\right)^2 = \left(g_V^p Z + g_V^n N\right)^2 \sim N^2$$

$$g_V^p = \frac{1}{2} - \sin^2\theta \qquad g_V^n = -\frac{1}{2}$$

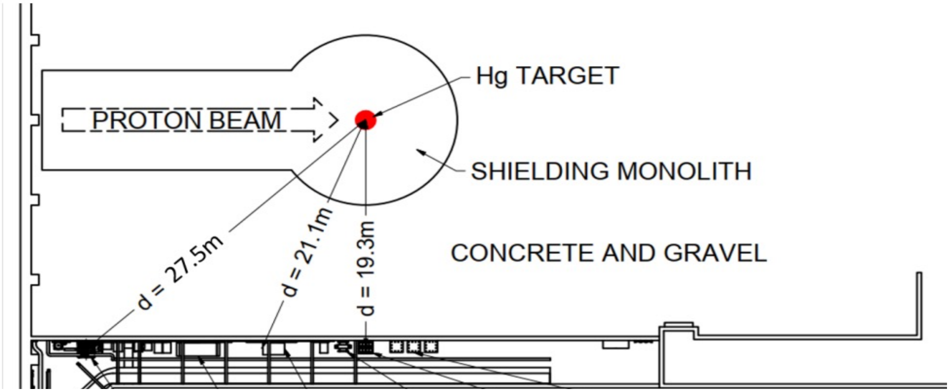
- Scales as the squared number of neutrons on the target

Sources for CEνNS measurements

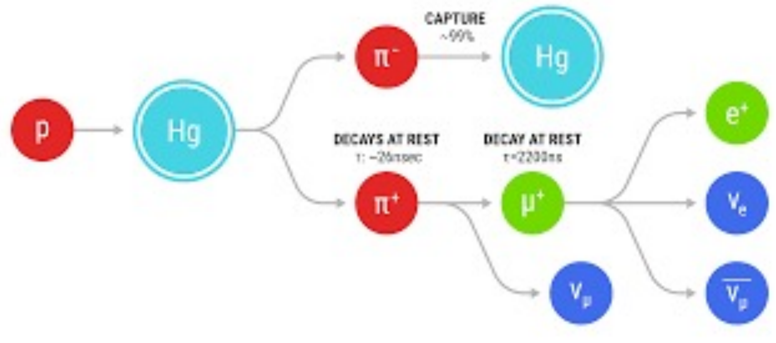
Current experiments and prospects.

Source	Characteristics	Collaborations
Spallation Sources	• Decay of pions at rest. • Up to 52 MeV. • Detected!	COHERENT, ESS (European Spallation Source)
Reactor Experiments	• Nuclear reactions. • Up to $\approx$ 8 MeV range. • Very low thresholds.	CONUS, CONNIE
Solar Neutrinos	• Reactions within the sun. • ^{8}B contribution. • Detected!	XENON, PandaX

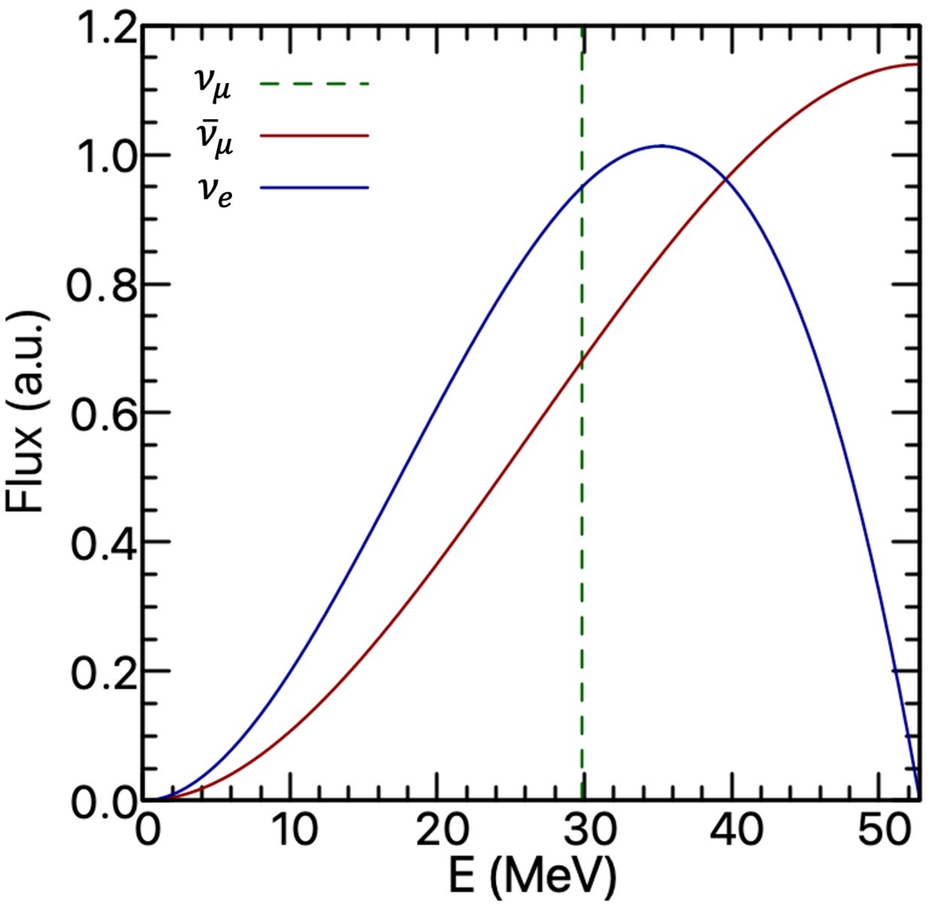
CEνNS at a Spallation Neutron Source



COHERENT Collaboration, Science 357 (2017) 6356

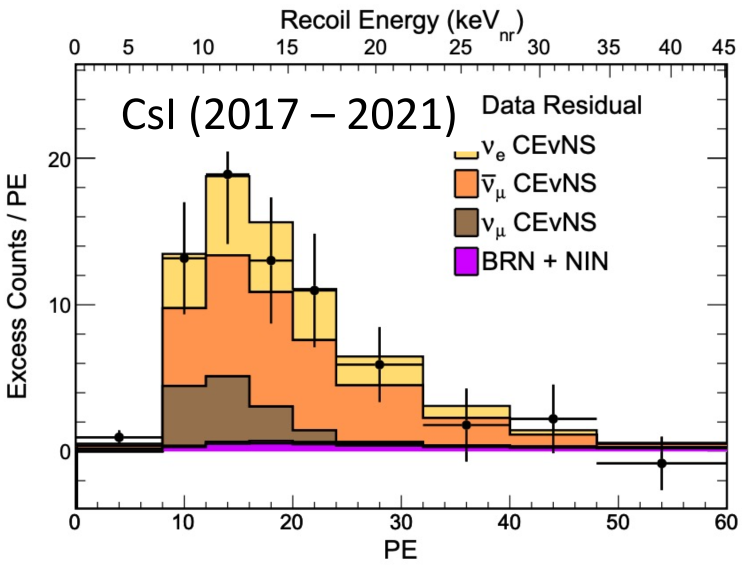


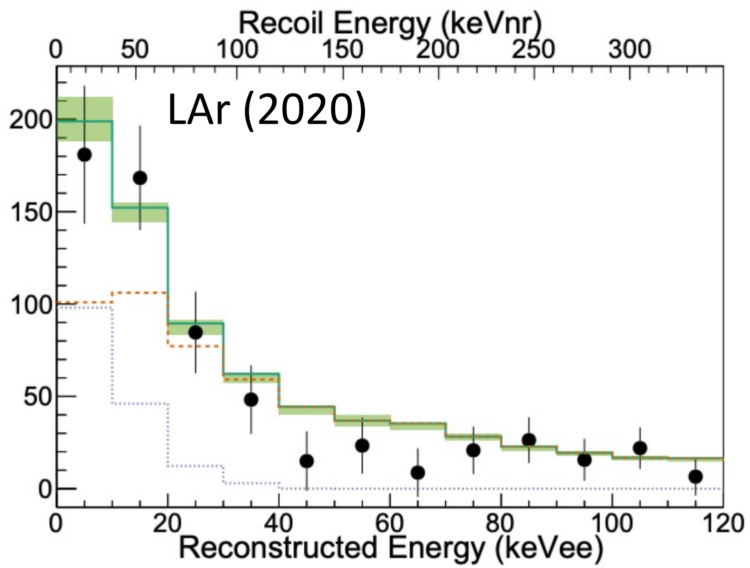
Production of neutrinos from pion and muon decay at rest.

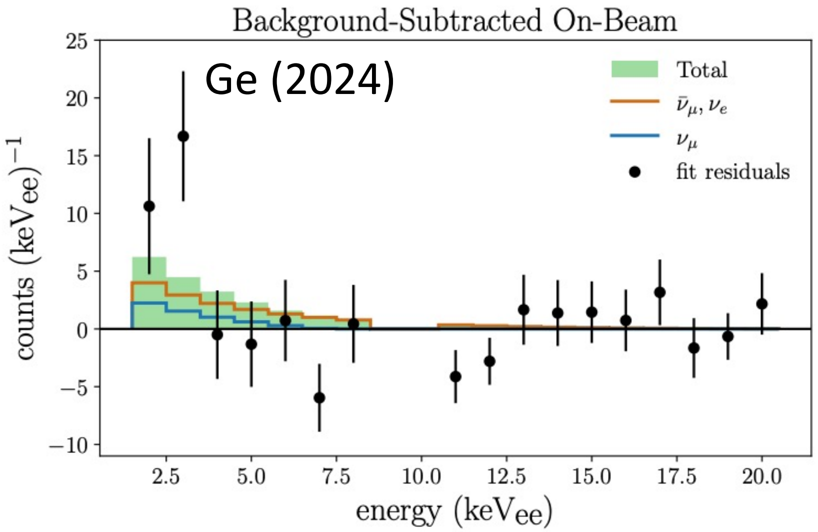


COHERENT Experiment

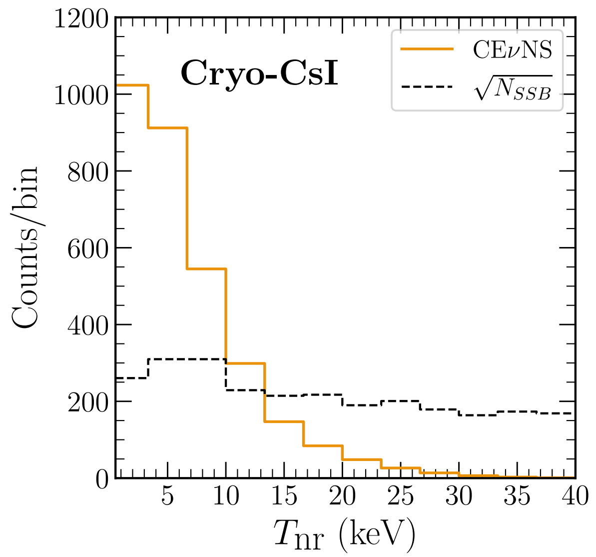
Current Detectors

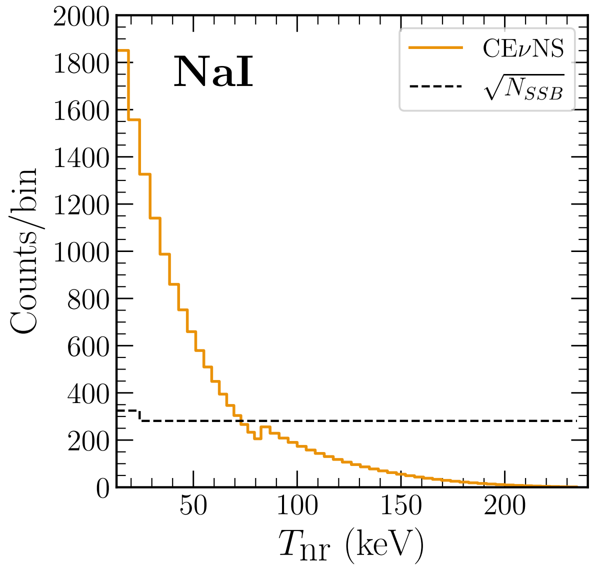






Future Detectors





References:

CsI: COHERENT Collaboration, Phys.Rev.Lett. 129 (2022)

CsI: COHERENT Collaboration, Science 357 (2017) 6356

LAr: COHERENT Collaboration, Phys.Rev.Lett. 126 (2021)

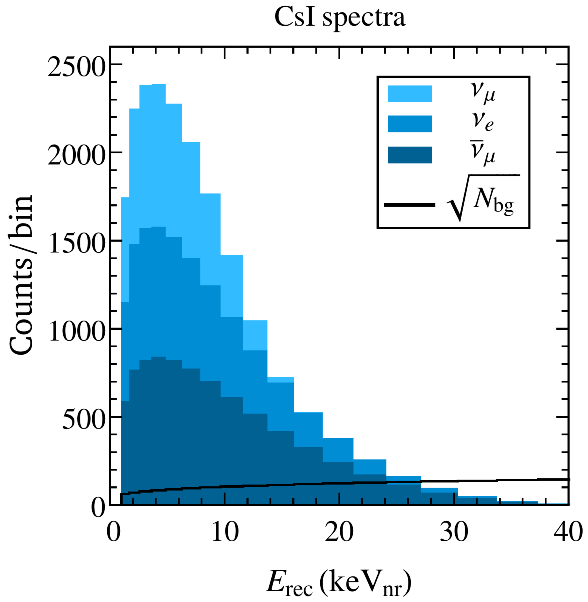
Ge: COHERENT Collaboration, arXiv 2406.13806

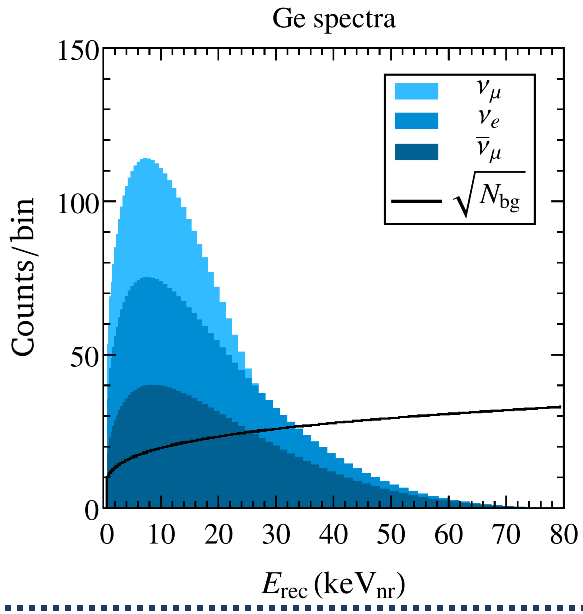
Cryo: COHERENT Collaboration, Phys.Rev.D 109 (2024)

NaI: COHERENT Collaboration, arXiv 2204.04575

European Spallation Source

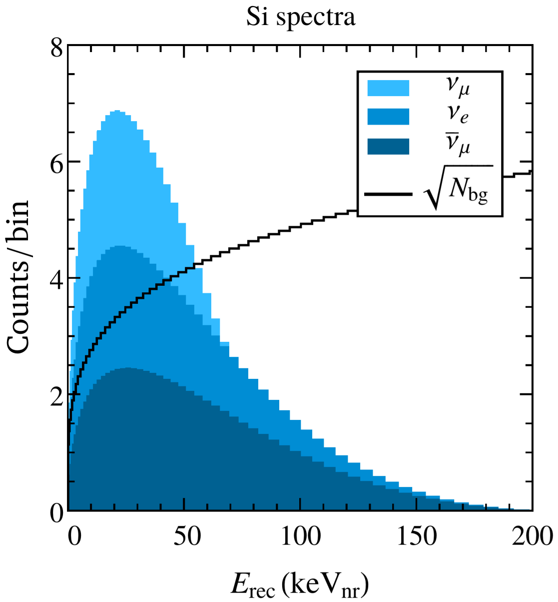
Future Detectors

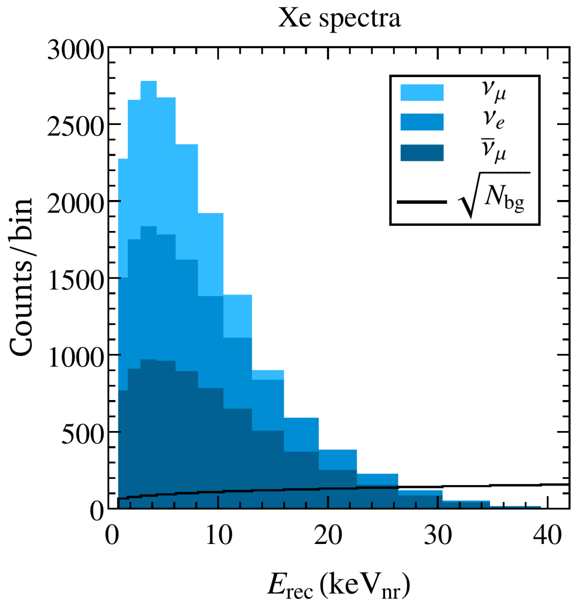




- Under construction in Lund, Sweden.
- Most intense pulsed neutron beams upon completion.
- Ideal for the study of CEvNS.
- Different proposed materials.

Future Detectors





References:

Baxter et all, JHEP 02 (2020) 123

Abele et all, Phys.Rept. 1023 (2023)

Phenomenology of CEvNS

A variety of models can be tested

Nicola's Talk

SM

θ_W **Weak Mixing Angle**

M. Cadeddu et al Phys.Rev. C 104 (2021)
D. Aristizabal et al JHEP 09 (2022) 076
V. De Romeri et al JHEP 04 (2023) 035
B. C. Canas et al Phys. Lett. B 784 (2018)

Neutron rms radius

M. Cadeddu et al Rev. Lett. 120 (2018)
O. Miranda et al JHEP 2005 (2020) 130
R. R. Rossi et al Phys. Rev. D 109 (2024)

New Physics

ε **Non-Standard Interactions**

P. B. Denton et al JHEP 04 (2021) 266
O. Miranda et al New J.Phys. 17 (2015)

μ **Magnetic Moments**

(Non-Standard Interactions and Magnetic Moments: This Talk)

T. Kosmas et al Phys.Rev. D92 (2015)
M. Atzori Corona et al JHEP 09 (2022) 164

q **Neutrino Millicharges**

C. Giunti, et al Phys.Rev.D 108 (2023)
M. Cadeddu, et al Phys. Rev. D 102 (2020)

(Christoph's Talk)

χ **Dark Fermion**

Phys.Rev.D 108 (2023) 5, 055001

(Valentina's Talk)

θ_W

Standard Model tests at low energies

Weak mixing angle and neutron rms radius – Current COHERENT

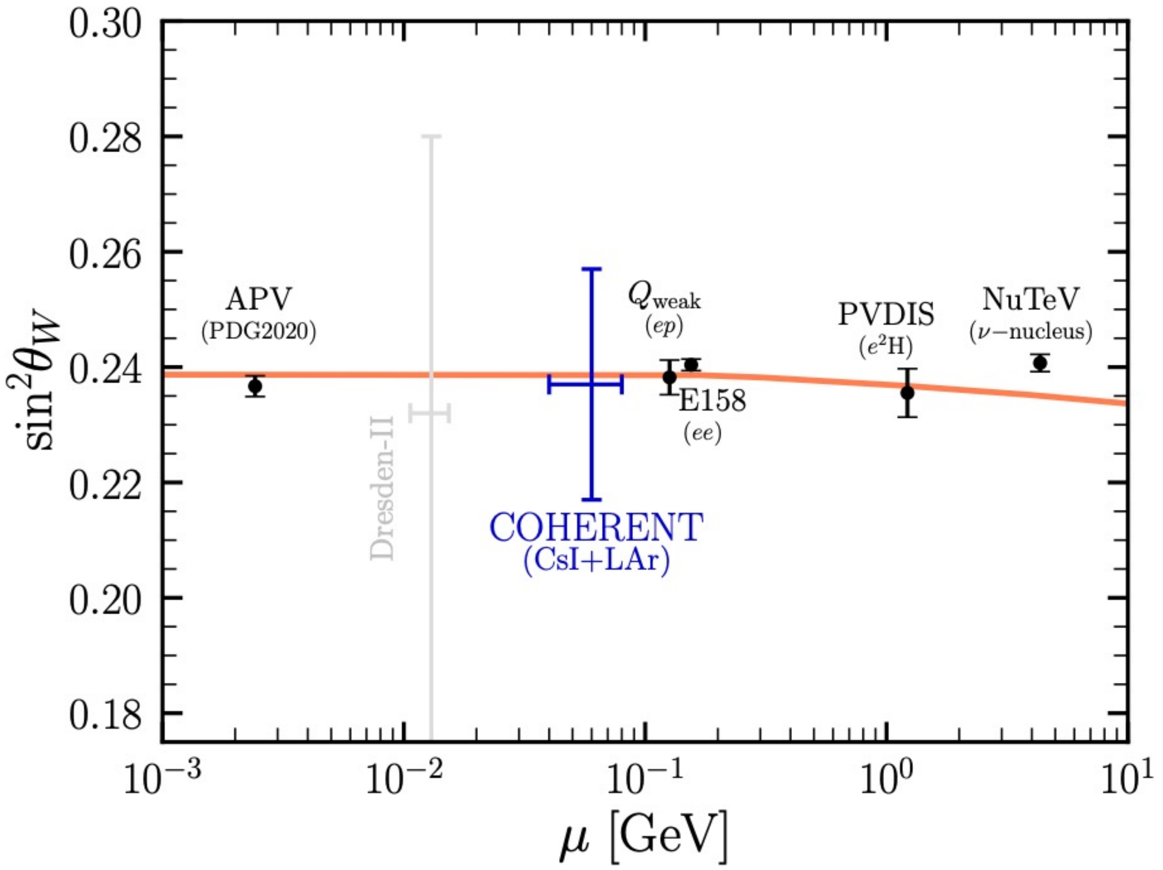
- Present in CEνNS cross section within the weak charge Q_W.

$$\left(Q_V^{SM}\right)^2 = \left(g_V^p Z + g_V^n N\right)^2$$

$$g_V^p = \frac{1}{2} - \sin^2\theta \qquad g_V^n = -\frac{1}{2}$$

- Measurement at low energies.

- Any deviation from SM prediction is a clear indicator of new Physics.



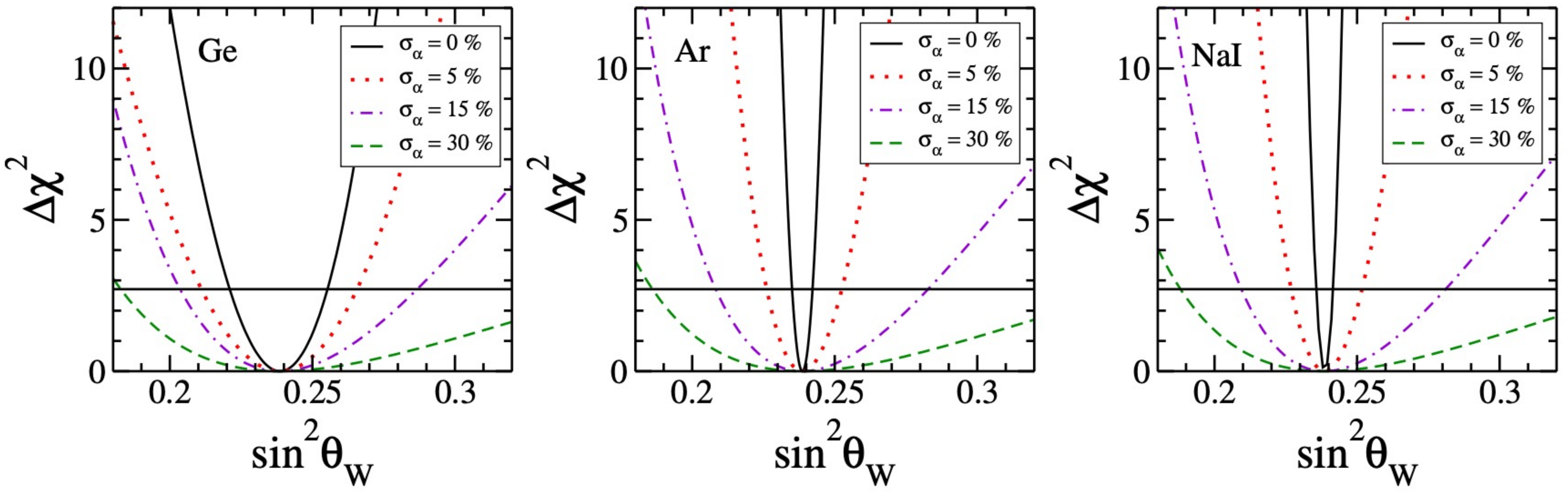
De Romeri, Miranda, Papoulias, **GSG**, Tórtola, and Valle, JHEP 04 (2023) 035

Standard Model tests at low energies

Weak mixing angle and neutron rms radius – Future COHERENT

θ_W

COHERENT - Expected



Miranda, **GSG**, and Sanders, Adv.High Energy Phys. (2019) 3902819,

Standard Model tests at low energies

Neutron rms radius

Average CsI neutron density distribution from COHERENT data

M. Cadeddu
Dipartimento di Fisica, Università degli Studi di Cagliari, and INFN, Sezione di Cagliari, Complesso Universitario di Monserrato - S.P. per Sestu Km 0.700, 09042 Monserrato (Cagliari), Italy

C. Giunti
INFN, Sezione di Torino, Via P. Giuria 1, I–10125 Torino, Italy

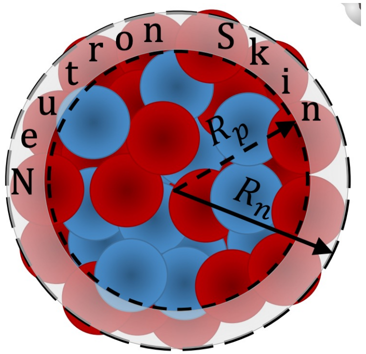
Y.F. Li and Y.Y. Zhang
Institute of High Energy Physics, Chinese Academy of Sciences, and School of Physical Sciences, University of Chinese Academy of Sciences, Beijing 100049, China

(Dated: 23 January 2018)

Using the coherent elastic neutrino-nucleus scattering data of the COHERENT experiment, we determine for the first time the average neutron rms radius of ^{133}Cs and ^{127}I. We obtain the practically model-independent value $R_n = 5.5^{+0.9}_{-1.1}$ fm using the symmetrized Fermi and Helm form factors. We also point out that the COHERENT data show a 2.3σ evidence of the nuclear structure suppression of the full coherence.

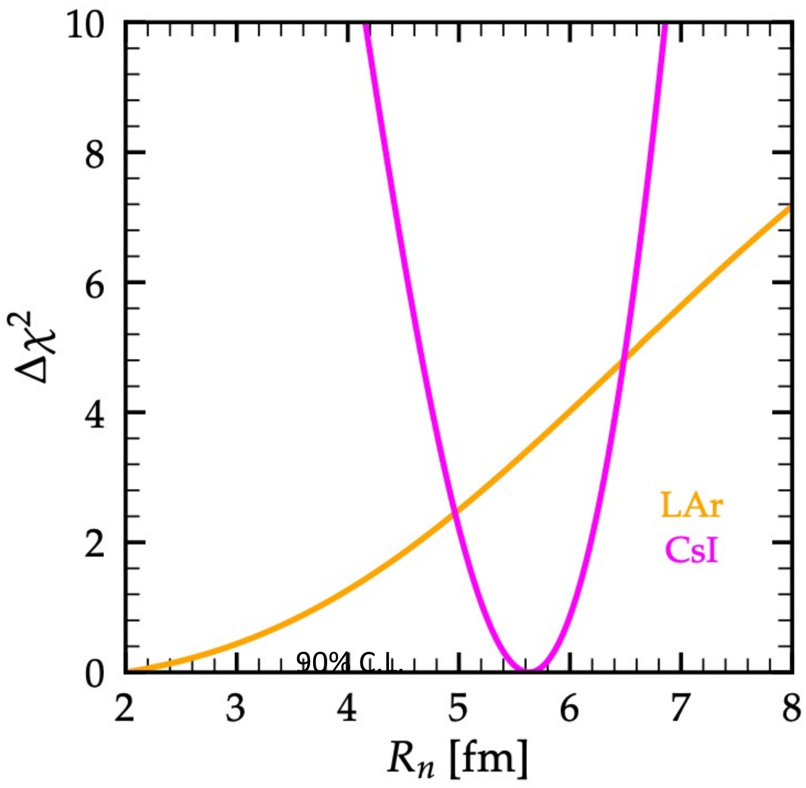
- Present in CE$\boldsymbol{\nu}$NS cross section within $F(q^2)$.

$$F_W(|\vec{q}|^2) = 3\frac{j_1(|\vec{q}|R_A)}{|\vec{q}|R_A}\left(\frac{1}{1+|\vec{q}|^2a_k^2}\right),$$



Cadeddu's Talk at NuFact 2018

- Fitted for targets as CsI and LAr .



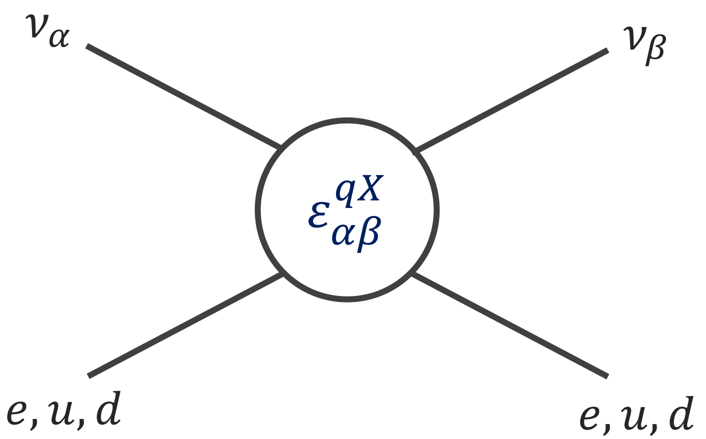
De Romeri, Miranda, Papoulias, **GSG**, Tórtola, and Valle, JHEP 04 (2023) 035

Beyond the Standard Model physics

Non-Standard Interactions

The Model

Neutral current Lagrangian introduced to allow for non-universal and flavor changing interactions.



$$\mathcal{L}_{\mathrm{NC}}^{\mathrm{NSI}} = -2\sqrt{2}G_F \sum_{q,\ell,\ell'} \varepsilon_{\ell\ell'}^{qX} (\bar{\nu}_\ell \gamma^\mu P_L \nu_{\ell'})(\bar{f}\gamma_\mu P_X f)\,,$$

Non-Universal NSI

Flavor dependent strength of interaction

ε_{ee}^{qV} $\quad$ $\varepsilon_{\mu\mu}^{qV}$ $\quad$ $\varepsilon_{\tau\tau}^{qV}$

Flavor Changing

Different neutrino flavor before and after the interaction.

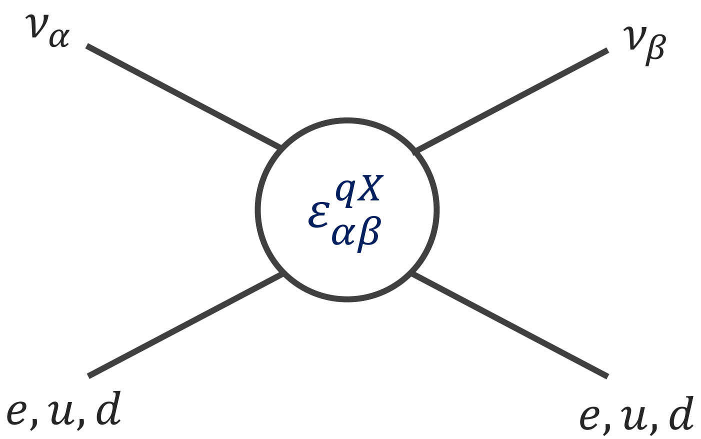
$\varepsilon_{e\mu}^{qV}$ $\quad$ $\varepsilon_{e\tau}^{qV}$ $\quad$ $\varepsilon_{\mu\tau}^{qV}$

Beyond the Standard Model physics

Non-Standard Interactions

The Model

Neutral current Lagrangian introduced to allow for non-universal and flavor changing interactions.



SNS sensitive

$$\mathcal{L}_{\rm NC}^{\rm NSI} = -2\sqrt{2}G_F \sum_{q,\ell,\ell'} \varepsilon_{\ell\ell'}^{qX} (\bar{\nu}_\ell \gamma^\mu P_L \nu_{\ell'})(\bar{f}\gamma_\mu P_X f)\,,$$

Non-Universal NSI

Flavor dependent strength of interaction

ε^{qV}_{ee} $\varepsilon^{qV}_{\mu\mu}$ $\varepsilon^{qV}_{\tau\tau}$

Flavor Changing

Different neutrino flavor before and after the interaction.

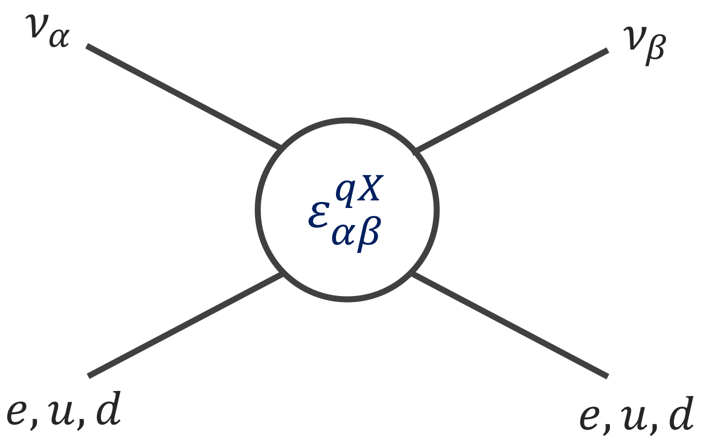
$\varepsilon^{qV}_{e\mu}$ $\varepsilon^{qV}_{e\tau}$ $\varepsilon^{qV}_{\mu\tau}$

Beyond the Standard Model physics

Non-Standard Interactions

The Model

Neutral current Lagrangian introduced to allow for non-universal and flavor changing interactions.



SNS sensitive

$$\mathcal{L}^{\text{NSI}}_{\text{NC}} = -2\sqrt{2}G_F \sum_{q,\ell,\ell'} \varepsilon^{qX}_{\ell\ell'} (\bar{\nu}_\ell \gamma^\mu P_L \nu_{\ell'})(\bar{f}\gamma_\mu P_X f)\,,$$

Solar sensitive

Non-Universal NSI

Flavor dependent strength of interaction

ε^{qV}_{ee} $\varepsilon^{qV}_{\mu\mu}$ | $\varepsilon^{qV}_{\tau\tau}$

Flavor Changing

Different neutrino flavor before and after the interaction.

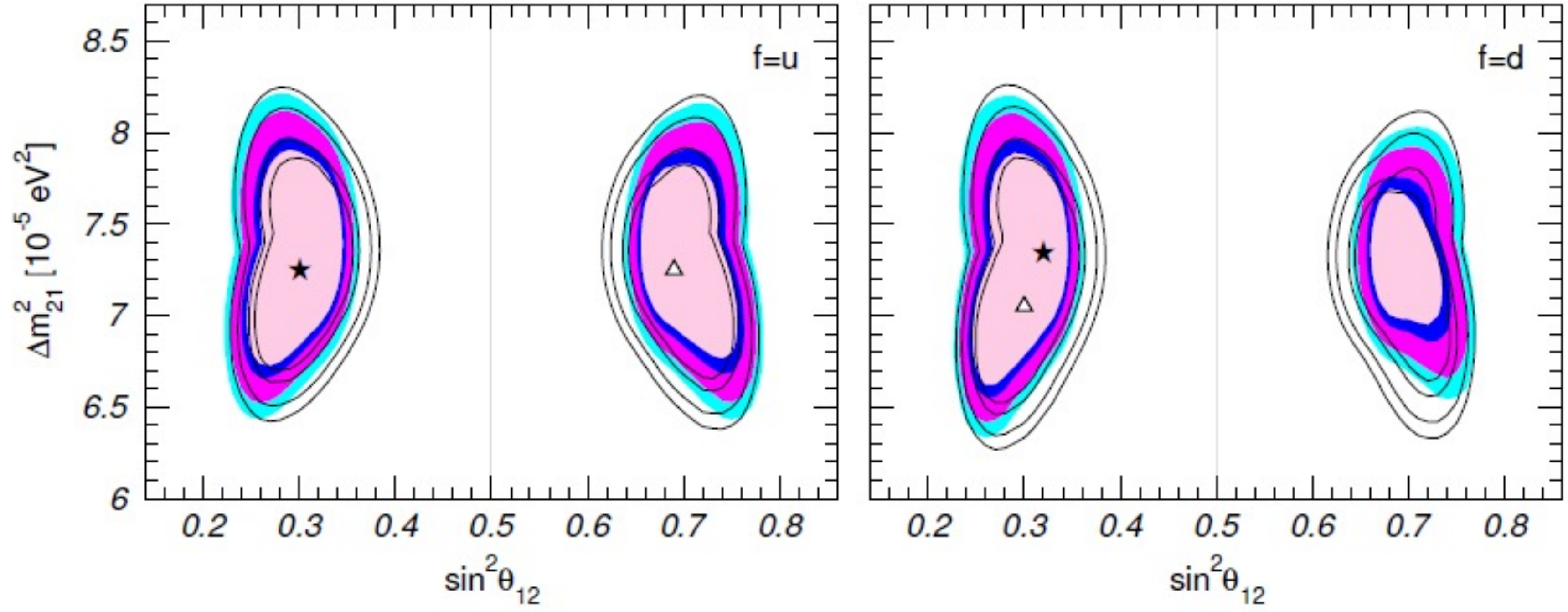
$\varepsilon^{qV}_{e\mu}$ $\varepsilon^{qV}_{e\tau}$ $\varepsilon^{qV}_{\mu\tau}$

Beyond the Standard Model physics

Non-Standard Interactions

Why are NSI important?

Effects on the determination of mixing parameters



M. C. Gonzalez-Garcia and M. Maltoni, JHEP 09 (2013) 152
O. G. Miranda, M. A. Tortola, and J. W. F. Valle, JHEP 10 (2006) 008

Beyond the Standard Model physics

Non-Standard Interactions

Effects on CEvNS Interactions

The weak charge is modified

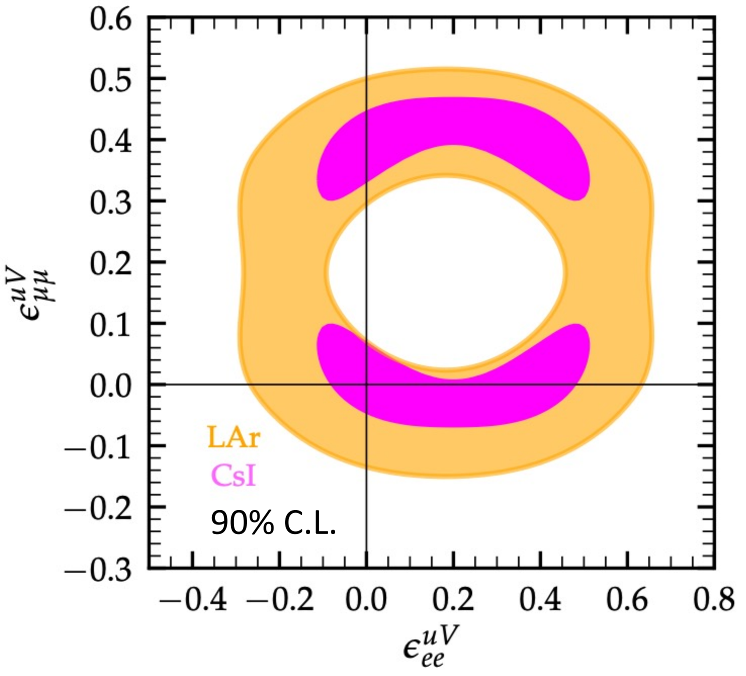
$$\left(Q_{W,\alpha}^{V}\right)^2 = \left[Z\left(g_V^p + 2\varepsilon_{\alpha\alpha}^{uV} + \varepsilon_{\alpha\alpha}^{dV}\right) + N\left(g_V^n + \varepsilon_{\alpha\alpha}^{uV} + 2\varepsilon_{\alpha\alpha}^{dV}\right)\right]^2 + \sum_{\beta\neq\alpha}\left|Z\left(2\varepsilon_{\alpha\beta}^{uV} + \varepsilon_{\alpha\beta}^{dV}\right) + N\left(\varepsilon_{\alpha\beta}^{uV} + 2\varepsilon_{\alpha\beta}^{dV}\right)\right|^2.$$

- Sensitivity to non-universal and flavor changing parameters.
- Interference with SM cross section for non-universal parameters.

Beyond the Standard Model physics

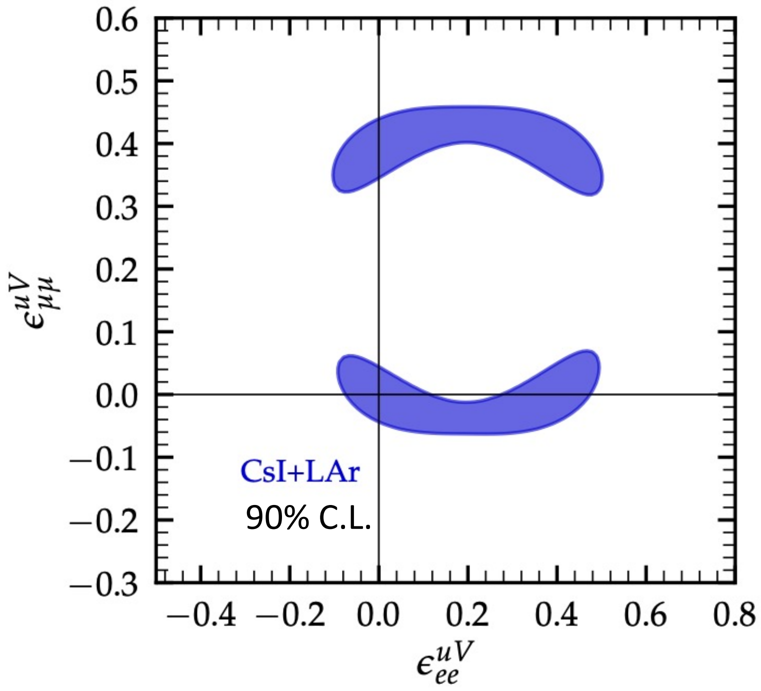
Non-Standard Interactions – Current COHERENT

Single Analysis



De Romeri, Miranda, Papoulias, **GSG**, Tórtola, and Valle, JHEP 04 (2023) 035

Combined



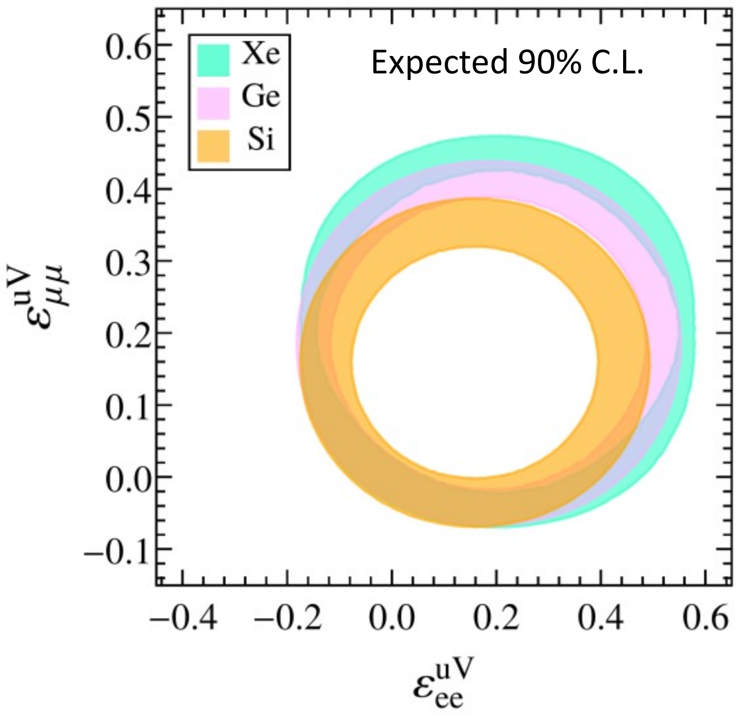
Other Bounds

Param.	Bound	Exp.
ε_{ee}^{dL}	[-0.3, 0.3]	CHARM
ε_{ee}^{dR}	[-0.6, 0.5]	CHARM
$\varepsilon_{\mu\mu}^{dV}$	[-0.042, 0.042]	Atm + Acc
$\varepsilon_{\mu\mu}^{uV}$	[-0.044, 0.044]	Atm + Acc

Beyond the Standard Model physics

Non-Standard Interactions – Expected ESS

Different Targets



Chatterjee, Lavignac, Miranda, and **GSG**,
Phys.Rev.D 107 (2023)

Each target material is sensitive to different regions of the parameter space.

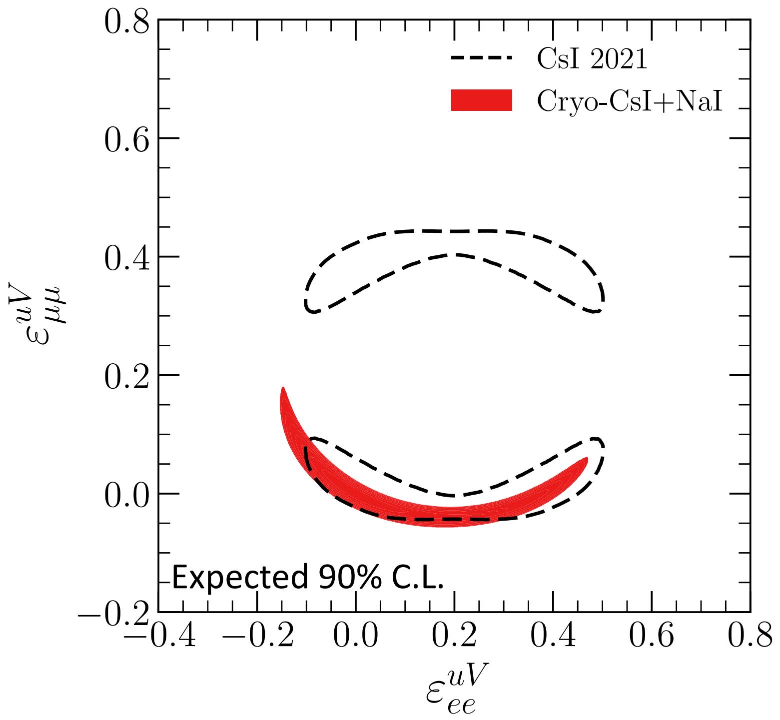
Position of the center depends on the number of protons and neutrons.

$$(h,k) = \left(\frac{Zg_V^P + Ng_V^N}{2Z+N}, \frac{Zg_V^P + Ng_V^N}{2Z+N}\right)$$

Beyond the Standard Model physics

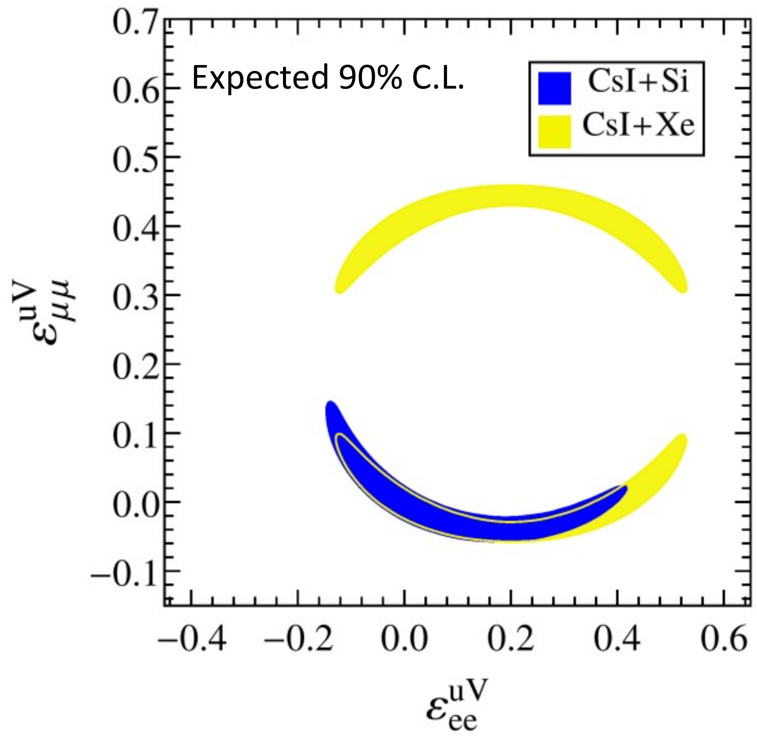
Breaking degeneracies

COHERENT - Expected



Chatterjee, Lavignac, Miranda, and **GSG**, arXiv 2402.16953

ESS - Expected

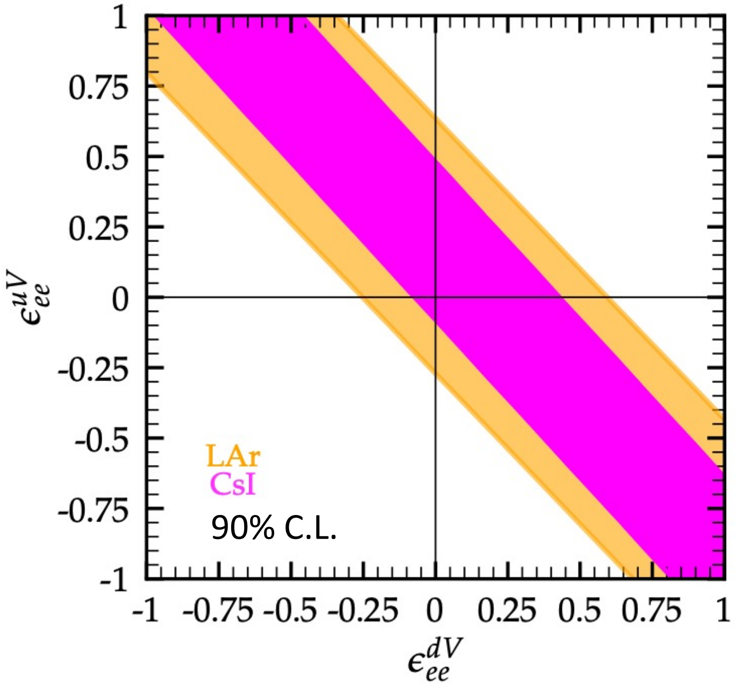


Chatterjee, Lavignac, Miranda, and **GSG**, Phys.Rev.D 107 (2023)

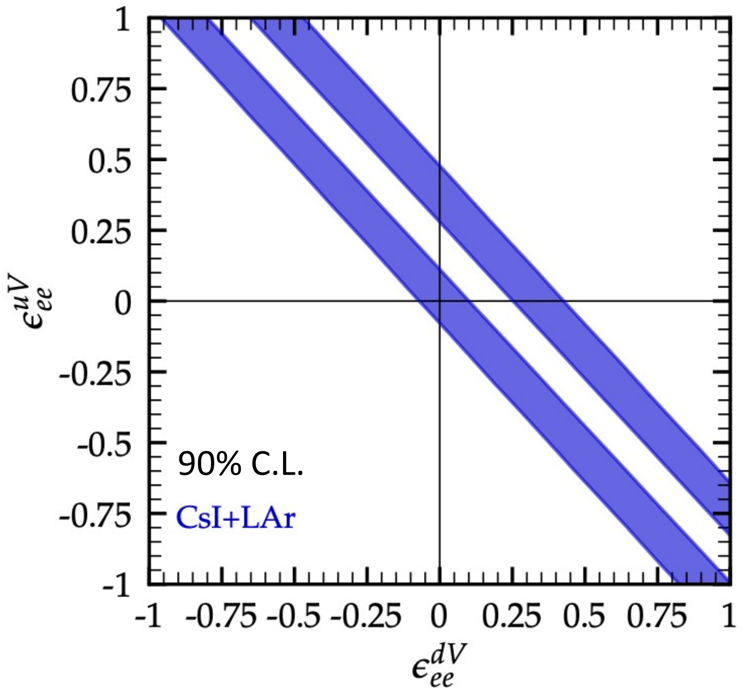
Beyond the Standard Model physics

Non-Standard Interactions – Current COHERENT

Single Analysis



Combined Analysis



De Romeri, Miranda, Papoulias, **GSG**, Tórtola, and Valle, JHEP 04 (2023) 035

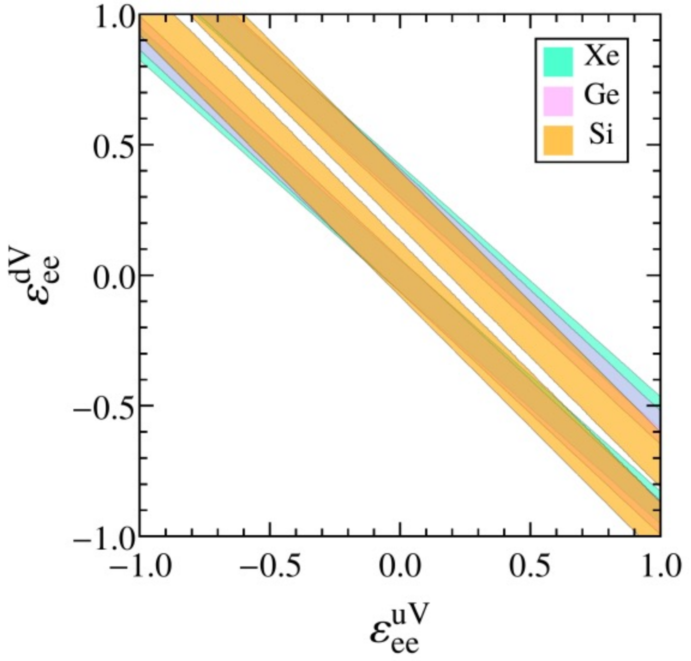
Other Bounds

Param.	Bound	Exp.
ε_{ee}^{dL}	[-0.3, 0.3]	CHARM
ε_{ee}^{dR}	[-0.6, 0.5]	CHARM
$\varepsilon_{\mu\mu}^{dV}$	[-0.042, 0.042]	Atm + Acc
$\varepsilon_{\mu\mu}^{uV}$	[-0.044, 0.044]	Atm + Acc

Beyond the Standard Model physics

Can we go further on breaking degeneracies?

ESS - Expected



Chatterjee, Lavignac, Miranda, and **GSG**, Phys.Rev.D 107 (2023)

Each target material is sensitive to different regions of the parameter space.

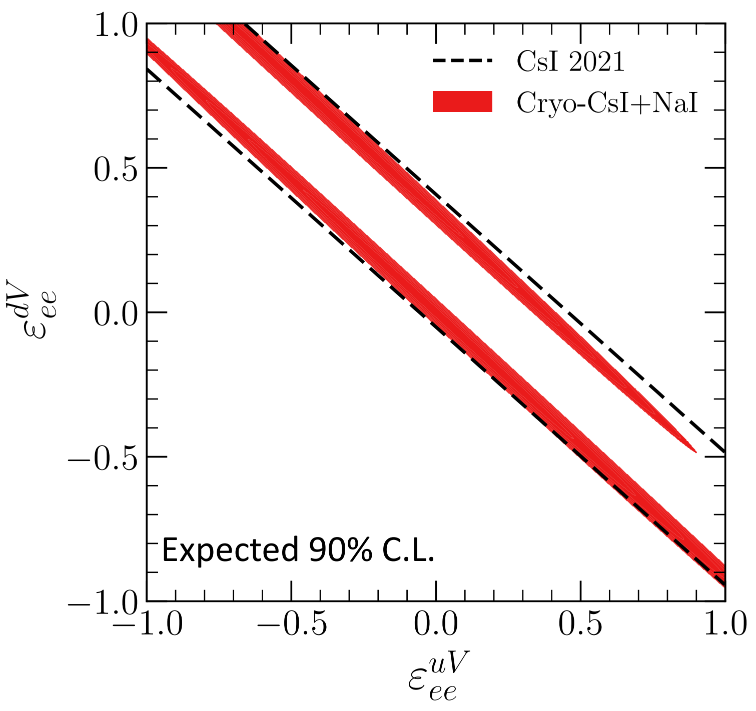
The slope of the band depends on the number of protons and neutrons.

$$m = -\frac{2Z+N}{Z+2N}$$

Beyond the Standard Model physics

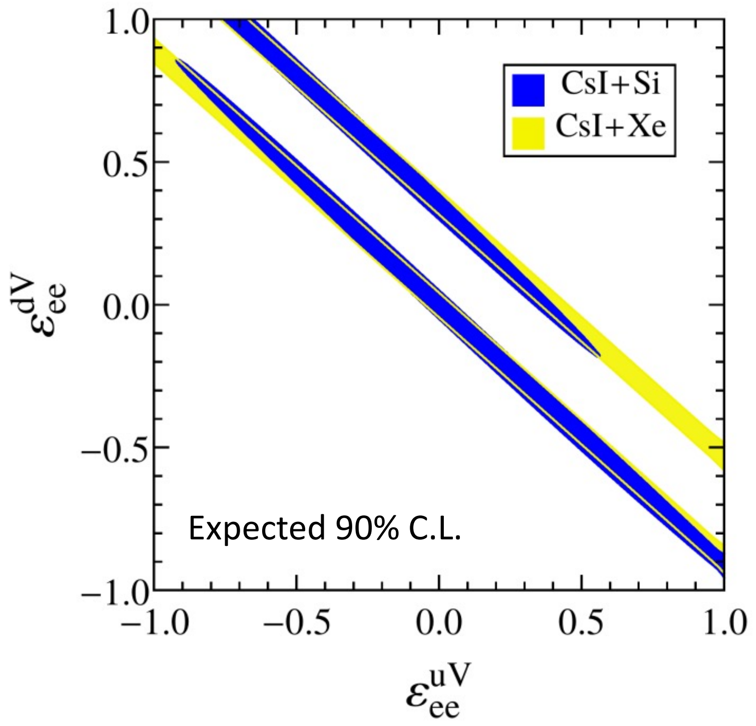
Breaking degeneracies

COHERENT - Expected



Chatterjee, Lavignac, Miranda, and **GSG**, arXiv 2402.16953

ESS - Expected



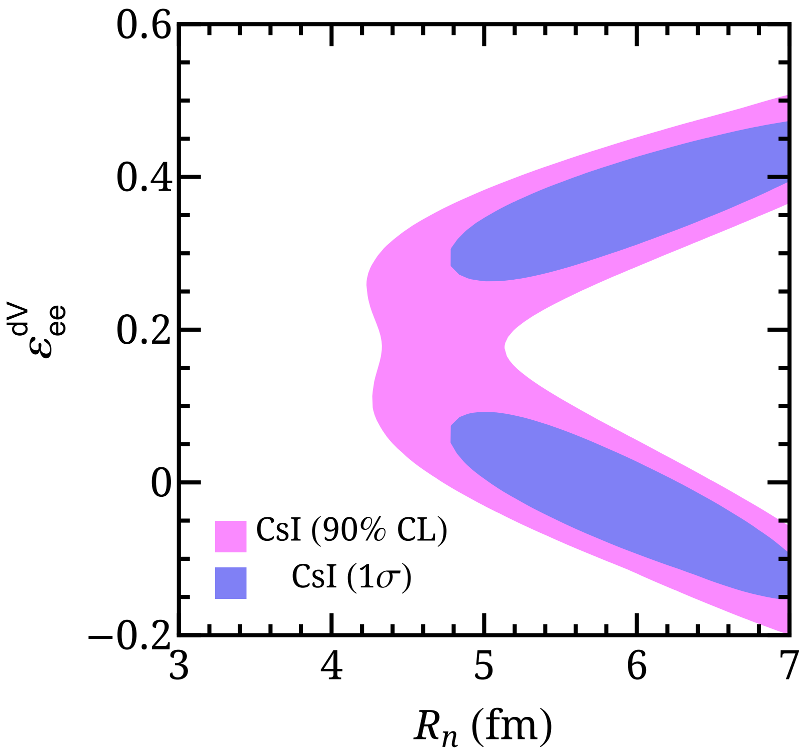
Chatterjee, Lavignac, Miranda, and **GSG**, Phys.Rev.D 107 (2023)

Interplay between SM and new physics

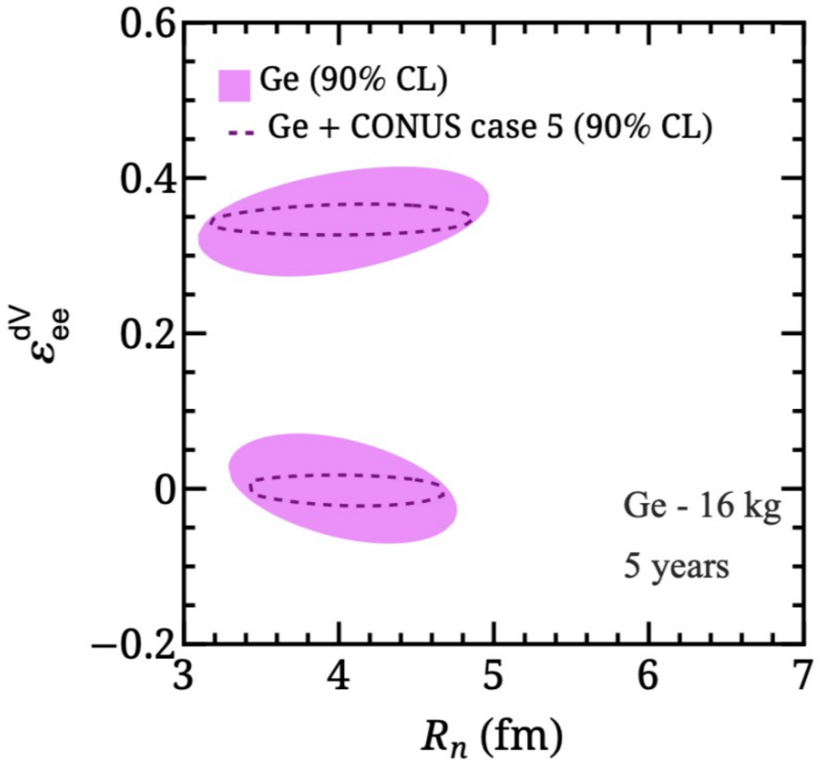
NSI and neutron rms radius

- Neutron rms radius brings uncertainties to the measurements.
- NSI parameters can be responsible for missing or excess events.
- There is an interplay between the neutron rms radius and NSI.

Current COHERENT



Expected Reactor + COHERENT



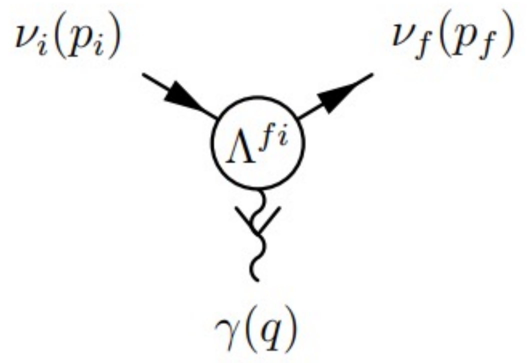
Rossi, **GSG**, and Tórtola Phys. Rev. D 109 (2024)

Beyond the Standard Model physics

Electromagnetic properties of neutrinos

The Model

Massive neutrinos can induce a neutrino coupling to the photon at loop level



Consistent with Lorentz and gauge symmetries

$$\Lambda_\mu^{fi}(q) = \left(\gamma_\mu - q_\mu \not{q}/q^2\right)\left[\mathbb{f}_Q^{fi}(q^2) + \mathbb{f}_A^{fi}(q^2) q^2 \gamma_5\right] - i\sigma_{\mu\nu} q^\nu \left[\mathbb{f}_M^{fi}(q^2) + i\mathbb{f}_E^{fi}(q^2)\gamma_5\right]$$

Neutrino Millicharge

$$f_Q(0) \equiv q_{\alpha\beta}$$

Neutrino Magnetic Moment

$$f_M(0) \equiv \mu_{\alpha\beta} \quad f_E(0) \equiv \epsilon_{\alpha\beta}$$

$$\lambda_{\alpha\beta} \equiv \mu_{\alpha\beta} + i\epsilon_{\alpha\beta}$$

Beyond the Standard Model physics

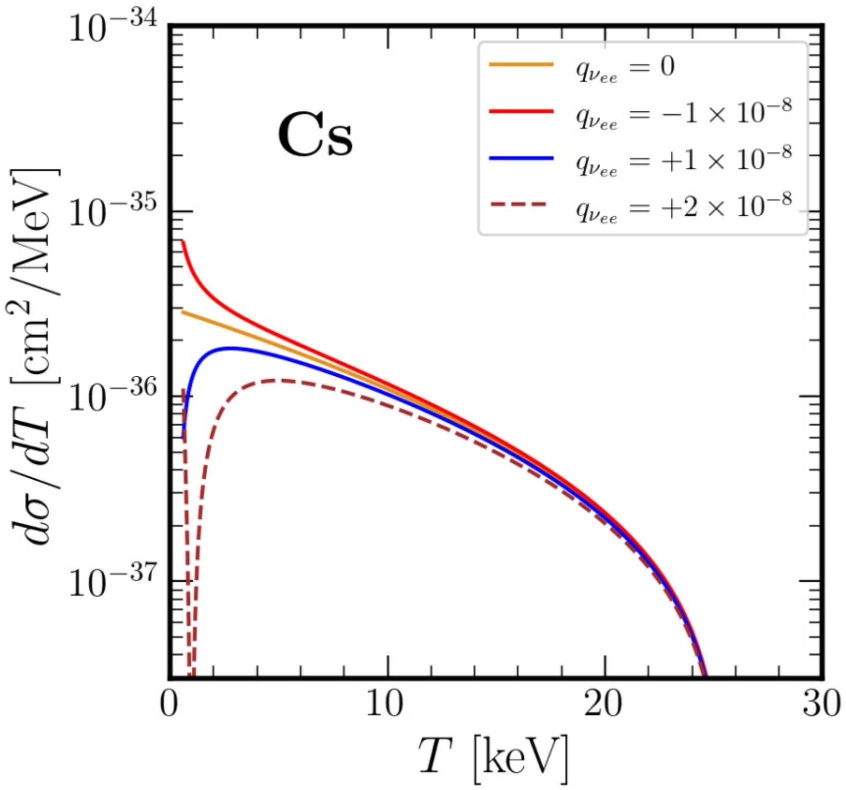
Neutrino Millicharges

Effects on CEvNS Interactions

Redefinition of coupling constant

$$\left(Q^V_{\rm MC}\right)^2 = \left(Q^V_{\rm W} + \frac{\sqrt{2}\pi\alpha_{\rm EM} Z}{G_F M}\frac{q_{\nu_{\alpha\alpha}}}{T}\right)^2 + \left(\frac{\sqrt{2}\pi\alpha_{\rm EM} Z}{G_F M}\frac{|q_{\nu_{\alpha\beta}}|}{T}\right)^2 .$$

- Sensitivity to millicharges at low energies.
- There is interference with SM cross section.

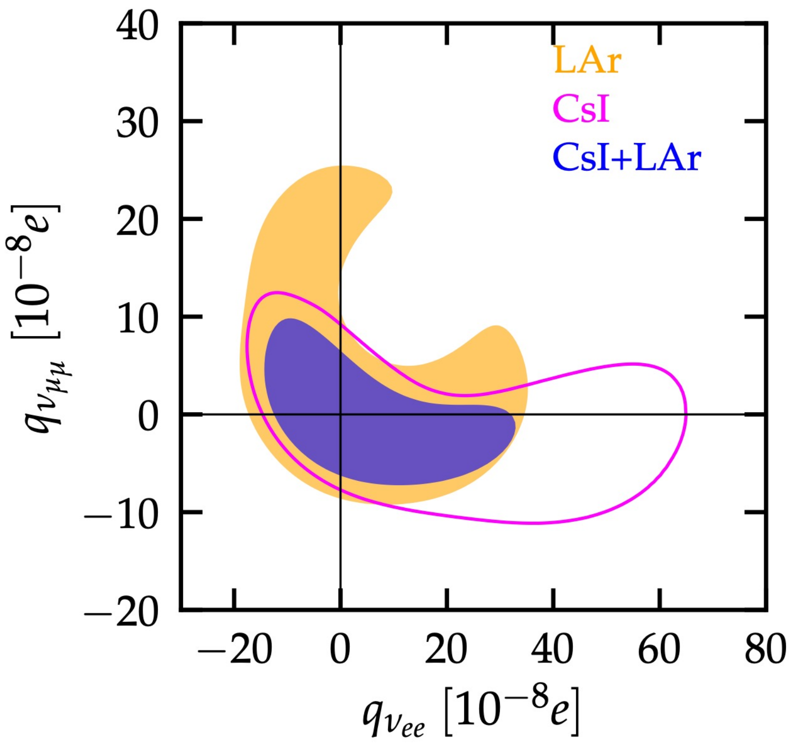


A. Parada and **GSG** arXiv 2409.10652

Neutrino millicharges

Electromagnetic properties of neutrinos

Current COHERENT



De Romeri, Miranda, Papoulias, **GSG**, Tórtola, and Valle, JHEP 04 (2023) 035

Other Bounds

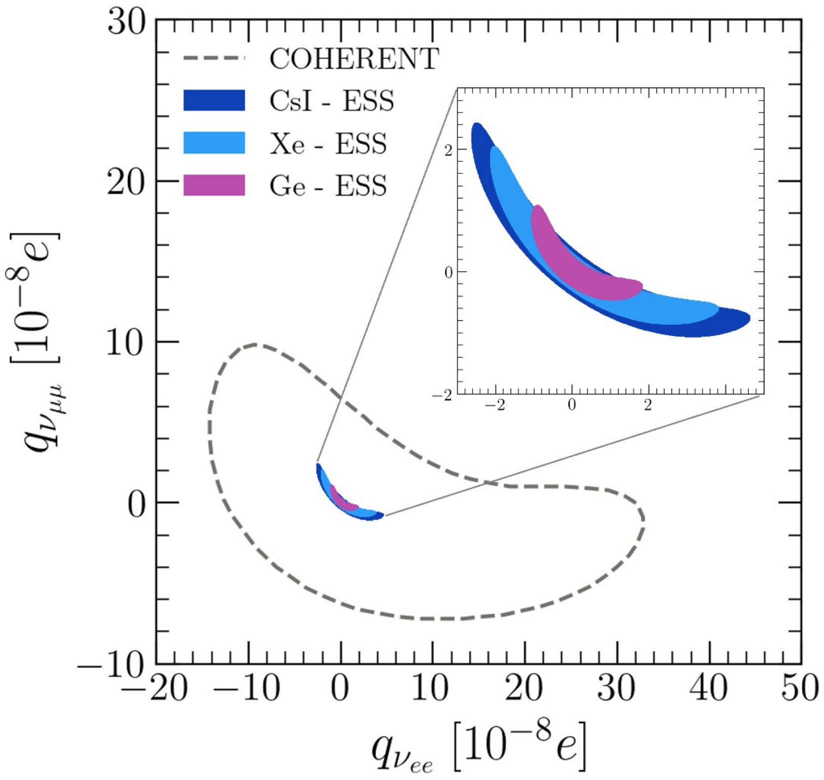
Param.	Limit [e]	Exp.
q_{ν_e}	3.7×10^{-12}	Reactor
q_{ν_μ}	6.8×10^{-10}	Direct Detection
q_{ν}	6.0×10^{-14}	Solar Cooling
q_{ν_e}	3.0×10^{-21}	Neutrality of Matter

- Strongest bounds coming from neutrality of matter.

Neutrino millicharges

Electromagnetic properties of neutrinos

Expected ESS



A. Parada and **GSG** arXiv 2409.10652

Other Bounds

Param.	Limit [e]	Exp.
q_{ν_e}	3.7×10^{-12}	Reactor
q_{ν_μ}	6.8×10^{-10}	Direct Detection
q_{ν}	6.0×10^{-14}	Solar Cooling
q_{ν_e}	3.0×10^{-21}	Neutrality of Matter

- Strongest bounds coming from neutrality of matter.

Beyond the Standard Model physics

Effective Neutrino Magnetic Moment

Effects on CEvNS Interactions

$$\left.\frac{d\sigma_{\nu_\ell \mathcal{N}}}{dE_{\rm nr}}\right|^{\rm MM}_{{\rm CE}\nu{\rm NS}} = \frac{\pi \alpha^2_{\rm EM}}{m_e^2}\left(\frac{1}{E_{\rm nr}} - \frac{1}{E_\nu}\right) Z^2 F_W^2(|\vec{q}|^2) \left|\frac{\mu_{\nu_\ell}}{\mu_{\rm B}}\right|^2 ,$$

- Sensitivity to the effective parameter $\mu^2_{\nu_\alpha} = \left(\lambda^\dagger \cdot \lambda\right)_{\alpha\alpha}$
- No interference with SM cross section.
- Relevant at low energies.

Effective Neutrino Magnetic Moment

Different depending on neutrino source

Solar Neutrinos

$\mu_{\nu_e} < 2.9\times10^{-11}\ \mu_B$

$$\mu^2_{\nu_\alpha} = \sum_{k=1}^{3} |U^{M}_{\alpha k}|^2 \left(U^\dagger \cdot \lambda^\dagger \cdot \lambda \cdot U\right)_{kk}$$

Accelerator Neutrinos

$\mu_{\nu_\mu} < 6.8\times10^{-10}\ \mu_B$

$$\mu^2_{\nu_\alpha} = \left(\lambda^\dagger \cdot \lambda\right)_{\alpha\alpha}$$

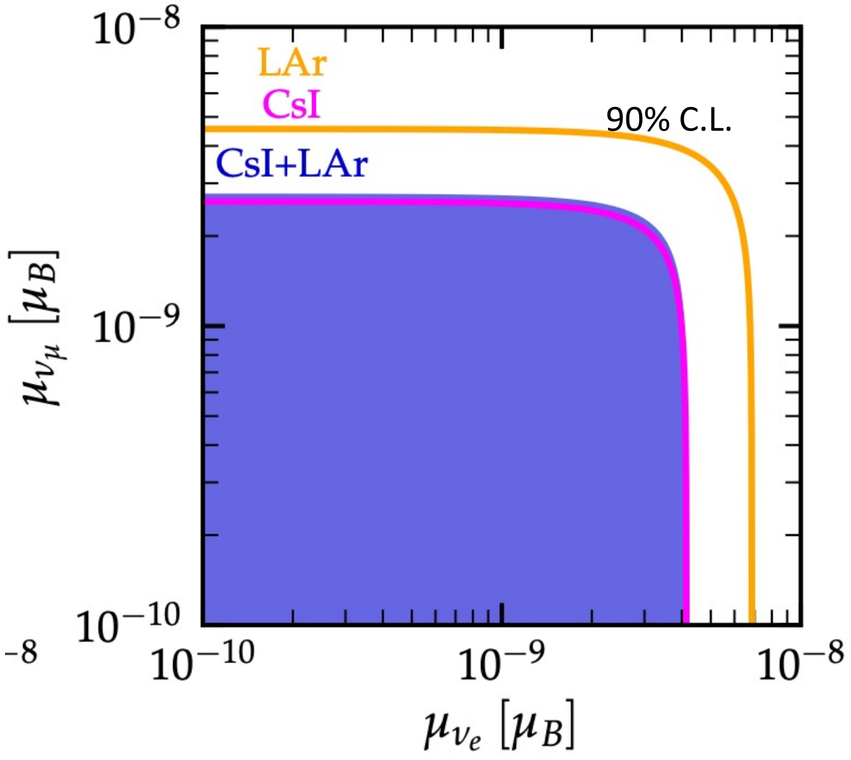
Reactor Neutrinos

$\mu_{\nu_e} < 2.9\times10^{-11}\ \mu_B$

$$\lambda_{\alpha\beta} \equiv \mu_{\alpha\beta} + i\epsilon_{\alpha\beta}$$

Effective Neutrino Magnetic Moment

Current COHERENT



De Romeri, Miranda, Papoulias, **GSG**, Tórtola, and Valle, JHEP 04 (2023) 035

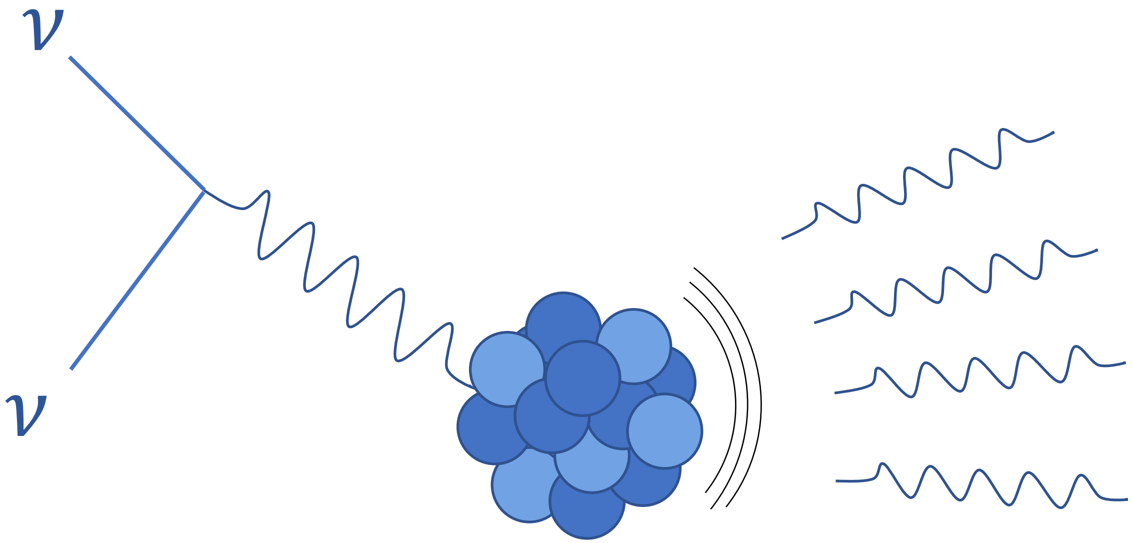
Other Bounds

Param.	Limit $[\mu_B]$	Exp.	Type
μ_{ν_e}	2.9×10^{-11}	GEMMA	Reactor
μ_{ν_μ}	6.8×10^{-10}	LSND	π−DAR
μ_{ν_τ}	3.9×10^{-7}	DONUT	π−DAR
μ_{ν_e}	2.8×10^{-11}	Borexino	Solar

Conclusions

- CEνNS is a powerful tool to perform tests of the SM.
- We can also use CEνNS to constrain new physics scenarios such as NSI, magnetic moments and millicharges.
- Combination of detectors can help to reduce degeneracies in the parameter space.
- Many different experiments are on their way to take more data.

Thank you!



IFIC INSTITUT DE FÍSICA CORPUSCULAR

CSIC

VNIVERSITAT DE VALÈNCIA

GENERALITAT VALENCIANA
Conselleria d'Educació, Universitats i Ocupació

MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES